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SOIL FERTILITY

BY

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SOIL FERTILITY.

MANURES AND COMMERCIAL FERTILIZERS.

All plants are made up of substances taken from the earth and the air. The roots of plants absorb water from the moist soil, and with it some of the solid parts of the earth dissolved in the water. When a plant is burned, the ash remaining is composed mainly of what came from the earth during the growth of the plant.

Plants, after becoming dry, have generally from 1 to 10 per cent of ash. The other 90 to 99 parts were derived from the air. Practically half the weight of dry plants is derived directly from the air through the medium of the leaves. All plant leaves absorb carbonic-acid gas—the gas that is used to charge mineral waters. This gas is easily produced by pouring strong acid on limestone. It is produced in nature on a vast scale by the burning and rotting of wood and other vegetable substances. It is also given off from the lungs of animals. When the leaves of plants absorb carbonic-acid gas from the air, the plants use the carbon (converting it into solid tissue), and give off oxygen gas, pure as originally. Oxygen for breathing is necessary to the life of man and animals. It is thus seen that animals and plants are dependent upon each other for the breath of life.

This mutual dependence does not stop here. Animals must have certain salts which help to make up the solid parts of the earth, in order to live and grow. But man and animals can not digest stone or earth. These earthy salts must be taken into plants and be combined there into substances digestible and nourishing to animals.

Then, the manure of animals is a good food for plants. When animals die their bodies also add fertility to the earth.

That a farmer can not enrich the air with plant food so as to benefit his crops is readily seen. This has been done successfully only in greenhouses, where the air can be controlled. All efforts in this direction must be mainly confined to adding plant food to the soil, or to improving the condition of the soil so that its own large stores of plant food may be more easily taken up by plants.

We may improve land chemically by adding to it manure, ground bone, nitrate of soda, or other rich substances; or we may improve it mechanically or physically, by draining, plowing, etc. Very often, and

it may be said generally, both kinds of improvement follow each operation. If manure is put upon land, it not only adds plant food to the soil but also loosens it, makes it drain better, and enables it to hold moisture better in time of drought. By rendering the soil more open and porous, the air can enter it more freely, causing many beneficial chemical changes to occur. Again, it is very well known now that many germs or bacteria (probably about the size of those that give us disease, but altogether friendly) feed on manures and other vegetable substances in the soil and perform many functions very necessary to make land highly productive.

New or freshly cleared land is generally productive, partly due to the large quantities of rotting leaves, stems, and roots of plants, and remains of dead insects contained. These keep it in good mechanical condition, so the air can enter and act chemically on the solid rock particles of the soil and make the plant-food elements soluble in water, so they can be used by plants. Then, as these organic remains of plants and animals decay completely, they furnish food directly to new plants. It may thus be seen that, if enough weeds, grass, and coarse manures, etc., are plowed under, old and worn land may be made fresh and fertile again.

Land in the Tropics appears to change in fertility very rapidly, or it wears out quickly. In a cold climate, where the ground is frozen for six or eight months in the year, the humus, or decaying vegetable remains referred to above, lasts for a great number of years. This humus is generally absolutely necessary to keep land productive; and in the Tropics, where rotting goes on all the time, the supply of humus becomes rapidly exhausted under constant cultivation. It is true that, when the land ceases to be cultivated, an enormous growth of weeds and grass, and often tropical jungle, comes and soon restores a large amount of rotting vegetable matter. Hence it is that in many tropical countries land is cleared and cultivated for from one to three years, and allowed to run wild six or eight.

Unless labor is very abundant and cheap, it will generally be found cheaper to keep up the fertility of the cleared land by growing restorative or fertilizing crops, and using manures and fertilizers.

All plants, as well as the crops we grow, are composed of about ten necessary chemical elements. Elements may be roughly defined as the "a b c" of matter. All matter is made up of combinations of elements. The scientists are continually discovering new elements, and they probably have a hundred by this time. Of the ten found necessary in plants, only three ever become scarce enough to necessitate their being added to the soils we cultivate. These three are nitrogen, phosphorus, and potassium.

Nitrogen comprises four-fifths of the air, but in this condition it is worth nothing to plants. They get carbon through their leaves, but they can not take nitrogen in this way. It must be found in some solid or liquid form in combination with other substances, as in animal manure,

nitrate of soda, oil cakes, or in the stores of nitrogen compounds in the soil. Nitrogen is also one of the most necessary elements of food for men and animals, but we can not appropriate to our needs what we breathe. We must get it in lean meat, eggs, milk, beans, pease, and, in lesser quantities, in most other foods.

Nitrogen is the soil element likely to become soonest exhausted, and the costliest one when we come to purchase it as a fertilizer. It will become exhausted more rapidly in a tropical country than in a temperate one. In the States nitrogen in fertilizers is rated at from 15 to 16 cents, gold, a pound. Here, no doubt, 20 cents would be a low price, if the fertilizer materials must be shipped from the States. While much more costly, pound for pound, than the other elements required for use in fertilizers, nitrogen does not generally have to be used in as large quantities as phosphoric acid.

Phosphorus, the fertilizer element generally required in largest quantity, is never found pure in nature. It is nearly always spoken of in agricultural and chemical works as phosphoric acid, and in this form is worth in America about 5 cents, United States currency, a pound. It is seldom utilized by plants in as large amounts as are potash and nitrogen, but it is scarcer and less available in soils and, hence, experience has proved that in using fertilizers more phosphoric acid should generally be used than either of the other ingredients.

Nor is potassium ever found pure in nature, but it is quite well known as potash, which is a compound of the metal potassium with the oxygen of the air. So we speak of potash when discussing the valuable ingredients of fertilizers. Its value in fertilizer materials is generally about 5 cents, United States currency, a pound.

Just what functions each of these ingredients performs in the development of the plant is not fully known. It is very well known that no plant could live if either one were lacking—nor, for that matter, in the entire absence of either of seven others found in plants.

Nitrogen in abundance is known to make plants grow vigorously and produce large, dark-green leaves. Phosphoric acid is known to be favorable to the production of seeds and to favor early maturity of plants. Potash is known to be essential as a carrier of starch from one part of a plant to another, and to fulfill other necessary offices in the plant economy.

A large source of nitrogen in nature is the nitrate of soda, or Chili saltpeter. This material contains 16 per cent of nitrogen, or 320 pounds per ton. Nitrate of soda has no other ingredient of any value as fertilizer. So if nitrogen is worth 20 cents a pound in Manila, a ton of nitrate of soda will be worth $64, United States currency.

Sulphate of ammonia is another source of nitrogen, and contains 20 per cent of this ingredient, or 400 pounds per ton. This, at 20 cents

a pound, will make its value as a fertilizer $80, gold. Sulphate of ammonia is a by-product in the production of coal gas, coke, etc.

Cotton-seed meal contains about 7 per cent nitrogen, and cocoanut cake about 3 per cent. These are, therefore, valuable as fertilizers, not only for their nitrogen but for their phosphoric acid and potash as well.

Dried blood, meat scrap, fish refuse, wool and leather wastes, and many other materials afford valuable sources of nitrogen for fertilizers.

Animal bone is rich in phosphoric acid. The phosphate rock, which is composed of the bones of prehistoric animals, is the largest source of this ingredient. The phosphate slag from the Bessemer steel works is also a valuable source of phosphoric acid. The phosphate rock, which is mined in many parts of the world, must be ground and mixed with sulphuric acid, to make its phosphoric acid soluble and available to plants. This combination makes the acid phosphate or superphosphate of commerce, and is by far the commonest form in which phosphoric acid is used as a fertilizer. A rich rock will produce an acid phosphate containing about 16 per cent of available phosphoric acid. There will also be a small precentage of phosphoric acid not available; because, if but slightly more sulphuric acid be used than just enough to combine with all the rock phosphate, a sticky mass will result that can not be handled. The phosphoric acid remaining unavailable to plants is considered as of very little value or none at all.

A good acid phosphate, then, will contain about 320 pounds of phosphoric acid to the ton. If worth 5 cents a pound in the United States, it will probably be worth 7 cents here, or $22.40 a ton. There is nothing else in the acid phosphate that is counted as having any value. About half of its weight is lime, to be sure, and this is no doubt beneficial to some crops and some soils.

Potash is generally abundant in the ashes of plants, and these are often used for fertilizing purposes. Muriate of potash contains 50 per cent of potash and, at 7 cents a pound here for the potash, would be worth about $70 a ton.[1] This salt, containing chlorine, injures the burning qualities of tobacco when used to fertilize this crop, and is otherwise injurious to many crops. Sulphate of potash is a better form in which to buy it. This contains 50 per cent potash and, hence, may be said to have a value of about $70 to $75, United States currency per ton.

It has generally been found the world over that fertilizers containing all three of the ingredients above discussed in suitable proportions are more profitable than those containing one or two of them. There are notable exceptions to this general rule which will be discussed later. These Islands being so far away from the sources of most of these

[1] The Strassfurt mines of Germany are the principal source of the world's supply of this ingredient.

materials, only the best grades should be shipped here, so as to effect a saving in freights and other charges.

There is still a great deal to be learned about the fertilizer requirements of soils and crops. It was once believed that an analysis of a crop would show its needs for fertilizers, the ingredients and the proportions in which these should be given. This idea is now known to be erroneous; yet assertions as to crop requirements based, it is believed, on no better evidence seem to be generally made and accepted to-day. For instance, it is almost universally claimed in agricultural literature that fruit and garden crops need much larger proportions of potash than cotton or grain crops. The potato is always credited with needing more of potash than of any other ingredient; yet late results of experiments indicate that potash is of much less importance than either nitrogen or phosphoric acid in the growth of the potato. The writer does not believe that the experimental evidence at all warrants the very common claim that fruit and truck crops generally need larger relative amounts of potash than other crops. In fact, the results of experiments have generally tended to minimize the usefulness of large amounts of potash as compared with the other two valuable ingredients.

There is a large class of crops not requiring nitrogen to be applied in fertilizers. These crops are the leguminosæ of the botanist, such as beans, pease, peanuts, clovers, and other pod-bearing plants. If one of these plants be dug up and the roots carefully washed, a great number of little wartlike growths will be seen on the roots. These tubercles are the abode of millions of bacteria, themselves minute living plants, that have the power of combining the nitrogen of the air and putting it in shape to be fed to the host plant. In this way a cowpea crop on an acre of land has frequently been known to get from the air 100 pounds of nitrogen. This quantity of nitrogen in fertilizers would be worth $20. Occasionally large velvet bean and peanut crops have been known to contain 200 pounds of nitrogen per acre. Of course, if these crops are allowed to rot on the land, or are plowed under, these large amounts of nitrogen become food for other crops and, hence, the legumes are generally called restorative or land-improving crops. If animals eat these crops, the manure produced will be richer than that made from the consumption of most other foods. Even when pease or beans are made into hay or otherwise gathered and removed from the land, the nitrogen contained in the roots and stubble still benefits the land greatly. It has often been found that, where a cowpea crop follows oats or wheat and is cut for hay, the crop the following year is benefited as much as it would have been by the application of several hundred pounds of rich fertilizer.

In the more progressive farming sections of the United States the nitrogen-consuming crops, such as corn, small grain, potatoes, cane, tobacco, and cotton, are regularly alternated with pease, beans, or clover.

In this way the fertility of the land is kept up, and better and larger crops are secured. Often the restorative crop is fertilized with phosphoric acid and potash. In this way its growth is greatly stimulated; hence, the amount of nitrogen gathered from the air is increased and the enriching effects of the legume are greater for the next crop.

It seems a great waste of resources to allow Philippine rice fields to lie idle from December to June. The land grows a crop of tough, coarse grasses. These burn off during the dry season instead of being plowed under to help keep up the fertility of the land. Then the roots of these grasses are often picked up while plowing for rice, and taken off the land. The land grows rice year after year with never a change. No other grain crop known to the writer would continue to yield profitable results under such soil management.

Suppose a piece of rice land should be cleared of its rice in December and promptly planted in Florida velvet beans. These beans will very soon cover the ground with a dense mass of foliage, and all foul grasses and weeds be completely choked out. A quantity of nitrogen will be added to the soil by rice-planting time in June and July and, whether the bean vines are taken off for stock feed or cut up and plowed under, the land will be very much enriched. Moreover, the weeds and grass will be so choked out that the rice will have clean ground in which to grow, and should make a greatly increased yield.

The Bureau of Agriculture succeeded in completely cleaning a piece of land of nut grass by growing velvet beans during the last wet season. Other plantings were made early in the dry season, and the beans have grown fully as well as they did in the wet season. Peanuts might grow on the rice land during the dry season, and make profitable crops, and yet the vines would considerably enrich the land. Cowpeas, mongoes, and other restorative crops would likewise give profitable food or forage crops, and also enrich the land for the regular rice crop; but no other crop will be found so effective in cleaning the land as velvet beans, and this is a very important matter in a tropical country. This crop leaves the land so clean, moist, and porous that very little plowing or other preparation is needed to fit it for starting another crop.

Over 100 acres of the Murcia rice farm have been planted in cowpeas and velvet beans, with the expectation of following with rice in June. On land naturally as thin and poor as this a very material increase in yield should result.

It is clear, then, that land may yield a regular crop every year indefinitely, and, if restorative crops (say, velvet beans) are grown regularly in the off seasons, the land will remain as fresh, as productive, and as free from obnoxious grasses as if it were freshly reclaimed from the forest. Since the restorative crop is a profitable food or fodder crop, it will more than pay for the work of growing, and keep up the land fertility

besides. This, then, is a very much more profitable practice than letting the land grow up in weeds, grass, and forest for a period of years.

The plan commonly practiced in Luzon, of growing one crop of sugar cane and then letting the land lie idle and grow up in weeds and grass for a year, could be immensely improved upon by the use of a fertilizer and growing one stubble or rattoon crop, and then running it in velvet beans for a year. In Negros the land is better and a rattoon crop is generally obtained, but the land is then fallowed or pastured a year or two. In every case where land lies idle, although it materially improves, it is costly and difficult to bring it into cultivation again, while a restorative crop like the velvet bean would enrich it more and be much cheaper to handle.

It may be asked if land growing a nitrogen-gathering crop each year will not soon become exhausted of phosphoric acid and potash. It may be said, generally, that land of good natural fertility, and especially the stiff clay and alluvial lands, if treated annually to a good dose of rich vegetable matter, such as a crop of velvet beans or cowpeas, will have an abundance of phosphoric acid and potash rendered soluble each year. In fact, the velvet-bean plant dried and analyzed would show over 2 per cent of potash—as rich in this ingredient as most commercial fertilizers. Two tons of the dry roots, leaves, and stems of this plant, plowed under on an acre, would give 80 or 90 pounds of potash in almost as good form for use by future crops as if applied as fertilizer. So, as long as restorative crops make large yields, it is proof enough that other crops following will not suffer for the want of any of the elements. True, there are large sections of sandy land, too poor to yield large restorative crops unless fertilized. On such beans and pease may be given phosphoric acid and potash in suitable form.

It is not believed to be at all true, as claimed by some, that all soils are naturally well enough supplied with plant food to yield maximum crops if only their physical condition were made good enough. Probably half of the cotton lands, and practically all of the early trucking lands of the United States, would seem to be rather large exceptions to prove such a rule. Direct applications of plant-food elements certainly pay handsomely over large sections of country, and the soils giving best results for these applications would seem to be physically more nearly perfect than most other soils.

Animal manures added to land have very much the same effect as the plowing in of restorative crops, or green manuring. The effects of manure from cattle, carabaos, or horses running on the grass will not be materially different from those of plowing in the grasses eaten to produce the manure. It will be somewhat quicker to rot and yield up its plant food. It is true that animals will generally pick the tender blades of grass, the young clovers, etc., that make richer food and richer manure than the average grasses and weeds that would be likely to be

plowed under. Animals eating grain, oil cake, beans, pease, or other rich food yield a richer and more valuable manure.

Where carabaos and pigs are kept, as they almost universally are in the Islands, in deep mud, it would certainly never pay to attempt to move the manure in this condition to the fields. If these animals could be kept in large pasture lots with small wallowing places, they would no doubt spend most of the time grazing on dry land and most of the manure would be dropped there where it might be plowed under from time to time and the pasture lot moved. So many carabaos are generally kept on a large farm that much land might be made fertile in this way. Horses and cattle may be kept in dry sheds on suitable bedding, as is done in the States, and the manure kept under shelter and taken to the field from time to time. Poultry manure is much richer than any other farm manure available, and should be carefully saved and applied to the land.

There are few farms in any country so favorably situated that maximum yields and profits can continue without rotating the crops, buying concentrated fertilizer materials, or doing both.

Bat guanos are plentiful in some parts of the Islands, but their composition is quite variable and none seem to be highly valuable. It is probably true that wet countries seldom possess highly valuable guano deposits. Except in the garrets of old churches occasionally, these bird deposits are subject to leaching, at least during the wet season. Where this is the case, the soluble nitrogen and phosphorus compounds are sure to be lacking. Guanos never have any potash of account. A few analyses so far made by the Government Laboratories of bat guanos follow, together with those of a few fertilizers and fertilizer materials whose compositions have either been determined here or are well known:

Name of material.	Nitrogen.	Available phosphoric acid.	Potash.	Estimated value in Manila per ton, United States currency.
	Per cent.	*Per cent.*	*Per cent.*	
Bat guano	4.25	4	Trace.	$22.60
Do	7.28	.24	0.905	30.00
Do	6.47	.202	.495	26.63
Nitrate of soda	16			64.00
Sulphate ammonia	20			80.00
Dried blood	13			52.00
Cotton-seed meal	7	3	1.5	34.30
Castor-oil cake	5.5	2	1	26.20
Coconut cake	3	1.6	2.4	17.60
Acid phosphate, good quality		16		22.40
Double superphosphate, sold by V. Jimenez Tortosa		39		54.60
Ground bone	4	22		46.80
Sulphate of potash			53	74.20
Muriate of potash			50	70.00
Meat scrap, dried	12			48.00
Fish scrap, dried	8	6		40.40
A complete fertilizer (containing all these ingredients), sold by Andrews & Co. in 1903	10	1.14	1.14	42.80
An average complete fertilizer, as sold for cotton in the United States	2	8	2	22.00

The valuations assumed, while derived from actual selling prices of the materials in the States, plus a liberal margin for freight and handling here, do not necessarily bear any fixed relation to what a dealer will charge in Manila. The prices will generally be found higher than those assumed but, in time, as fertilizers come to be dealt in on a larger scale, they will be handled more economically and sold on smaller margins.

FERTILIZER LAWS SUGGESTED.

Until such time as the Philippine Islands shall have laws enacted—such as are on the statute books of nearly every State in the Union, compelling all people dealing in fertilizers to have them analyzed and sold on a guaranty of quality—it will be much safer for planters to buy standard materials and mix them themselves than to buy ready-mixed fertilizers whose composition can not be detected. Until fertilizer laws became general and came to be rigidly enforced, the frauds practiced in the fertilizer trade were enormous. Of course, any buyer can protect himself by having fair samples of the fertilizers he buys analyzed before purchasing.

It would be well to bear in mind that nitrogen in its different forms is not equally available for plants. As a nitrate it is immediately ready to be absorbed by plants. Nitrate of soda applied to a grain or grass crop will often show its effects in two or three days in the dark-green color it gives the foliage of the crop. As it occurs in sulphate of ammonia, cotton-seed meal, or fish scrap, it must go through chemical changes in the soil, have its nitrogen combined with oxygen of the air, and be changed into nitrates before it can feed the plants. These changes require time and, hence, the latter materials are not as quick in action as the nitrate of soda; but they last longer, and are often capable of furnishing nitrogen to a crop during its entire growth. Nitrate of soda, or any nitrate for that matter, is very easily washed from the soil and, hence, should never be applied in large quantity during the wet season. A better practice at all times would be to apply this very soluble ingredient in small quantities to a growing crop, so that it may be immediately used. Applied in this way it has often proved to add such strength and vigor to a crop that its power of getting mineral food, phosphoric acid, and potash from the natural stores in the soil is greatly increased.

It can well be believed that, say, from 50 to 75 pounds of nitrate of soda, carefully sprinkled in the plow furrows near the sugar cane in April and May, when there is just rain enough to properly dissolve and distribute the material, would greatly stimulate growth, promote health and vigor, and result in quite a profitable increase in yield of sugar. This advice would presuppose that the land is not new, but old and worn, so as to need nitrogen, and, further, that the land is cleaned of weeds and grass at the time of the application, so that the cane can reap the entire benefit of the application. Such treatment would certainly be still more bene-

ficial to a rattoon crop on any but quite fresh and new land. If large quantities of nitrogen are to be used, most of it should be given in the form of sulphate of ammonia or some animal or vegetable source, so that it may slowly become available and not be leached away and wasted.

One need not be so economical in the use of the minerals, phosphoric acid, and potash. These form rather stable compounds in the soil and do not wash away easily.

It would, no doubt, be better in a country like this, where crops have a long period of growth, not to apply all the chemical fertilizer at one time, but to use it in smaller quantities and make two or three applications. This is often found profitable, even where crops have a short season of growth, and where chances for loss are much less than here.

FERTILIZER MIXTURES, OR COMPLETE FERTILIZERS.

A complete fertilizer is one containing all three of the fertilizer ingredients. In making mixtures it has been found profitable to use a small quantity of the readily soluble nitrate of soda, and a larger quantity of the more slowly available nitrogen materials like sulphate of ammonia, cotton-seed meal, dried blood, or tankage. A mixture that ought to give good results here would be made up of 1,300 pounds of 16 per cent acid phosphate, 200 pounds nitrate of soda, 350 pounds sulphate of ammonia, and 150 pounds sulphate of potash. These materials should be thoroughly mixed together, and would make a ton of complete fertilizer, containing about 10.4 per cent available phosphoric acid, 5 per cent of nitrogen, and 3.75 per cent of potash. A mixture like this would be considered quite a high-grade complete fertilizer, and 500 to 800 pounds per acre would be considered a good application for cane or tobacco. A mixture of 1,250 pounds ground cocoanut-oil cake, 700 pounds 16 per cent acid phosphate, and 50 pounds sulphate of potash would make a mixture nearly as good as the average fertilizer sold for cotton in the States.

About twice the amount of this would be needed per acre as of the higher grade mixture.

Only tobacco, sugar cane, and a few other crops that have high money value per acre are given these large applications of fertilizer. Corn would probably be given 150 to 300 pounds of high-grade fertilizer, and cotton not that much. Pease, peanuts, or velvet beans would be given about 100 pounds acid phosphate mixed with 20 pounds muriate or sulphate of potash. Larger yields of crops, proportionately, are always gotten from small applications of fertilizers rather than from large applications. The best profits are usually obtained from moderate applications, rather than from very small or very large ones.

In making a mixture of fertilizers (we will say, for sugar cane), if the land is very much worn, as shown by a small growth of crop inclined

to be yellow in color, it will likely be best to increase somewhat the nitrogen in the mixture. For rattoon crops a little more nitrogen would be needed than with the first year's crop. If the land is very sandy, a little more potash will probably be needed; while, if very stiff, less would be indicated. For a crop on somewhat new land, or land that has been lying idle or growing restorative crops so that the growing plants look green, vigorous, and flourishing, less nitrogen would be indicated as being necessary.

One can order from the manufacturers of fertilizers a mixture containing, say, 10 per cent available phosphoric acid, 5 per cent nitrogen (either or both forms discussed above), and 3 per cent of potash, or any other combination desired.

Contrary to popular opinion, soil analysis seldom teaches exactly what is needed to be used in fertilizers. It gives certain indications to one knowing how to interpret the results. Taken in connection with such observations as are mentioned above, it is believed a fairly correct answer can be given as to what crops need in the way of fertilizers.

RICE, HEMP, AND COCOANUTS.

So far very little is known experimentally as to the needs of these three staple crops of this Archipelago. Rice is known to respond well to the use of restorative crops and animal manures in China and Japan. Its splendid growth on new, fresh land would plainly indicate its liking for nitrogen. Just how much the excessive amounts of water required for rice would complicate results in fertilizing rice with concentrated fertilizers is not known to the writer.

Hemp, too, flourishes remarkably on newly cleared land full of humus. In a few years, after the excess of humus has disappeared from the land, the plants become yellow and unthrifty. They at least do their best when they have an abundant supply of nitrogen. It is also quite likely that phosporic acid and potash are needed.

It is a matter of common observation that cocoanut trees, near houses where they have yard sweepings, poultry manure, and other fertilizing substances, bear many more and finer nuts than do those in the main part of a grove. J. Ferguson, author of The Cocoanut Palm, says it is well established that the trees need mainly nitrogen and phosphoric acid. He claims that with 70 trees per acre, 500 pounds of cow manure per tree, well cultivated into the soil of mature trees have been known to increase the yield 4,200 nuts per acre. Mr. Ferguson also says that poonac, or cocoanut-oil cake, and castor cake are fine fertilizers for cocoanut trees. The fact that the cocoanut is so often found growing on sandy beach land would indicate that potash may also be scarce enough to be used profitably together with the other ingredients.

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PRINCIPAL COMMERCIAL PLANT FIBERS.

BY

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PRINCIPAL COMMERCIAL PLANT FIBERS.

By Lyster H. Dewey,

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Introduction.

One of the most important manufacturing industries of this country is that which includes the various lines of textiles. Leaving out the silk and woolen mills, which use chiefly animal fibers, there are the cotton factories, the linen and jute mills, and the twine and cordage mills, which use plant fibers exclusively. These number about 1,200 distinct establishments, representing an invested capital of more than $500,000,000 and giving productive employment to more than 300,000 persons.

The source of the raw material required by this great industry is an item of no small interest. Most of the cotton is produced in our Southern States, but nearly all the other vegetable fibers are imported. The importations of raw fibers, including cotton, during the fiscal year ended June 30, 1903, amounted to $46,161,172. These figures cover only the raw fiber. The importations of all the different kinds of textile plant fibers in the various stages of manufacture, from yarn and coarse twine to fine woven goods, laces, and hosiery, amount annually to more than $80,000,000.

Classification of Fibers.

Vegetable fibers used in textile manufactures in this country may be readily divided into three rather distinct classes, either from the standpoint of the manufacturer, who regards the kind of machinery or process of treating the fiber and the character of the goods produced, or from the viewpoint of the botanist, who regards the character of the plant and the manner in which the fiber is borne. These three classes are:

(1) The cottons, with soft, lint-like fiber ½ inch to 2 inches long, composed of single cells, borne on the seeds of different species of cotton plants.

(2) The soft fibers, or bast fibers, including flax, hemp, and jute; flexible fibers of soft texture, 10 to 100 inches in length, composed of many overlapping cells, and borne in the inner bark of the plants. (Pl. XLV, fig. 1.)

(3) The hard, or leaf, fibers, including manila, sisal, mauritius, New Zealand fibers, and istle, all having rather stiff, woody fibers 1 to 10 feet long, composed of numerous cells in bundles, borne in the tissues of the leaf or leaf stem. (Pl. XLV, fig. 2.)

COTTONS.

Cotton easily outranks both of the other classes combined in the quantity used, the capital invested in its production and manufacture, and the diversity of its uses. It is produced at a comparatively small cost, is spun into yarn with greater ease and rapidity than any other vegetable fiber, and is readily adapted to nearly all forms of woven fabrics. These facts have led to its extensive use among all civilized nations.

AMERICAN UPLAND COTTON.

Among the half dozen rather distinct types of cottons recognized by producers and manufacturers the most extensively used is the American Upland (Pl. XLVI, fig. 1). This is cultivated in the Southern States from Virginia to Oklahoma and Texas. It has given such good results here that seed has been taken to all other cotton-growing regions, and now American Upland cotton is cultivated in Russian Turkestan, Persia, India, British and German West Africa, Brazil, and Porto Rico.

There are more than a hundred recognized horticultural varieties of Upland cotton in cultivation, all belonging to one botanical species, *Gossypium hirsutum*, native in the American tropics. The original wild plants in the tropical zone were perennials, but the plant is cultivated as an annual. The seed is sown in the spring, in drills, rarely in checks, and cultivated in the same manner as corn. The lint, or cotton of commerce, is borne on fuzzy seeds in seed pods ("bolls"—Pl. XLV, fig. 3) which burst open at maturity (September to November in the Southern States), exposing the fluffy wool-covered seed clusters ready for picking. The lint is separated from the seeds by ginning and packed in bales for shipment.

The average annual production of Upland cotton in the Southern States during the past five years has ranged between 9,500,000 and 11,000,000 bales of 500 pounds each. The prices during this period have varied from 6 to 16 cents per pound. The value of the crop, more than $500,000,000, exceeds that of any other crop, except corn, produced in this country.

The lint of Upland cotton consists of fibers one-half inch to 1½ inches in length, white, appearing when highly magnified like flattened tubes or collapsed fire hose, spirally twisted. This twist enables the fibers to cling together, making a strong thread when spun; furthermore, it permits them to bend without breaking, enabling them to be spun into a hard-twisted, yet flexible, yarn or thread.

Upland cotton is spun into yarn, and the yarn is twisted into sewing thread, wrapping twine, or small sizes of rope, is braided into cord, knit into hosiery, or woven into cloth, ranging from the standard unbleached factory goods to fancy velveteens and novelties in colors. Raw cotton is also mixed with wool, and cotton yarn often appears as a mixture in woolen, silk, and linen goods.

SEA ISLAND COTTON.

Sea Island cotton is obtained from a plant known technically as *Gossypium barbadense* (Pl. XLVI, fig. 2). This species was found in the West Indies when Columbus first visited those islands. The best varieties of Sea Island cotton have been developed by careful seed selection and cultivation on James and Edisto islands, along the coast of South Carolina. This cotton is cultivated on other islands and the adjacent mainland in that region, and also in sandy soils in the interior, across southern Georgia and northern Florida. Fresh supplies of seed are brought from the coast every two or three years to keep up the quality of that grown in the interior. During the last two years the cultivation of Sea Island cotton has been reintroduced into Porto Rico and the British West Indies, and under improved conditions it seems likely to become more profitable there than before it was crowded out by the sugar industry.

The Sea Island plant differs from that of Upland cotton in its larger growth—3 to 8 feet high, with longer and more flexible branches, more deeply lobed leaves, bright yellow flowers, and sharp-pointed bolls, having three instead of four or five divisions or locks (Pl. XLV, fig. 3). The seeds are black or dark brown, and are not covered with a persistent fuzz. The lint is 1⅝ to 2 inches long, finer and longer than that of Upland cotton, and usually softer and more lustrous. It commands a price ranging from 2 to 15 cents per pound more than Upland cotton, but it requires greater care in its production and is more exacting in regard to soil and climate. It yields less per acre (100 to 300 pounds), and costs more to pick and to gin. It is used in making fine threads for sewing and for laces, fine yarns for fancy hosiery, for weaving into the finest lawns and dimities, and generally for the most expensive grades of cotton goods.

An important derivative of Sea Island cotton is that known as long-staple Upland, obtained by careful selection from hybrids of Sea Island and Upland cotton. The long-staple Upland cottons are cultivated chiefly in the rich alluvial soil of the Yazoo delta in Mississippi. The lint is intermediate in character between Sea Island and Upland cotton.

EGYPTIAN COTTON.

Another still more important derivative of the Sea Island type is Egyptian cotton, cultivated on the irrigated lands of Egypt, where

scarcely any rain falls from the time the seed is planted in March until the last of the crop is picked in November. Many generations of growth under these conditions, and possibly some hybridization with India cotton, have developed a peculiar quality of lint especially adapted to the manufacture of hosiery yarns and mercerized goods. The United States imports Egyptian cotton to the value of $7,000,000 to $10,000,000 each year, and the demand is steadily growing, owing to the increasing use of knit goods and the continued popularity of the silk-like mercerized cotton goods.

INDIA COTTON.

The cotton of East India, next in importance, is obtained chiefly from a species of plants native in southern Asia, *Gossypium herbaceum* (Pl. XLVI, fig. 3). The plants differ from American Upland cotton in their more slender, less woody stems, with leaves having roundish instead of sharp-pointed lobes, and in the smaller, more nearly spherical bolls (Pl. XLV, fig. 3). The lint of some varieties is glossy white, of others dull, of some yellow, and of still others golden brown. It is generally coarser and shorter than American Upland cotton, ranging from one-half to an inch in length. Outside of India it is used chiefly for medium or coarse yarns and for mixing with other cotton. Very little of it is imported into this country. It is cultivated in Farther India, China, Bengal, Persia, Arabia, and the Levant.

PERUVIAN COTTON.

In South America, Peruvian cotton (*Gossypium peruvianum*) is cultivated chiefly in Brazil and Peru. This cotton, often called kidney cotton, is characterized by the seeds in each lobe of the capsule clinging together in a compact cluster. These seeds are black and without a persistent fuzzy covering. The lint shows a wide variation in color and texture—white, brown, reddish, rough and harsh, or smooth and soft. Most of it has a shorter, coarser, and more wiry fiber than that of American Upland. The lint of some varieties is much like wool in appearance. It is imported chiefly for mixing with wool or for producing special effects. Kidney cotton is found in Central America and also in the Philippines and other tropical islands of the Pacific, but it is not cultivated in commercial quantities outside of South America.

SOFT FIBERS.

FLAX.

The flax plant (*Linum usitatissimum*—Pl. XLVII, fig. 1) originated in western Asia in the region between the Caspian Sea and the Persian Gulf. It was doubtless one of the earliest plants cultivated for fiber, and from the times of the first authentic record until the advent of

FIG. 1.—SOFT FIBERS.

[*A*, Flax; *B*, Hemp, dew-retted; *C*, Hemp, water-retted; *D*, Jute.]

FIG. 2.—HARD FIBERS.

[*E*, Manila; *F*, Sisal; *G*, Mauritius; *H*, Istle.]

American Upland. Sea Island. India.

FIG. 3.—COTTON BOLLS.

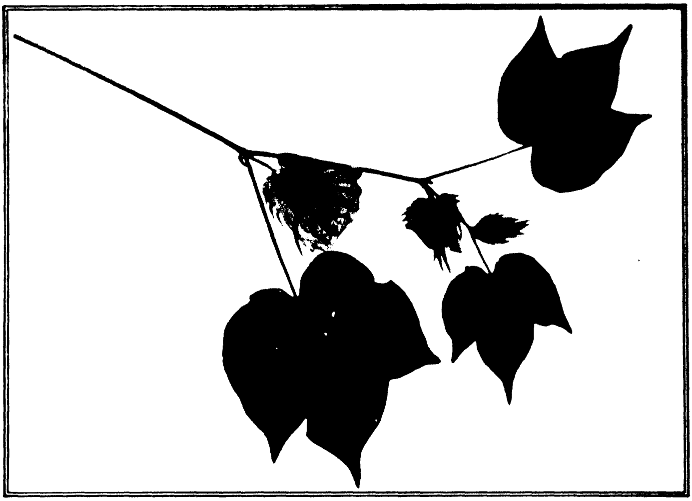

FIG. 1.—AMERICAN UPLAND COTTON (GOSSYPIUM HIRSUTUM).

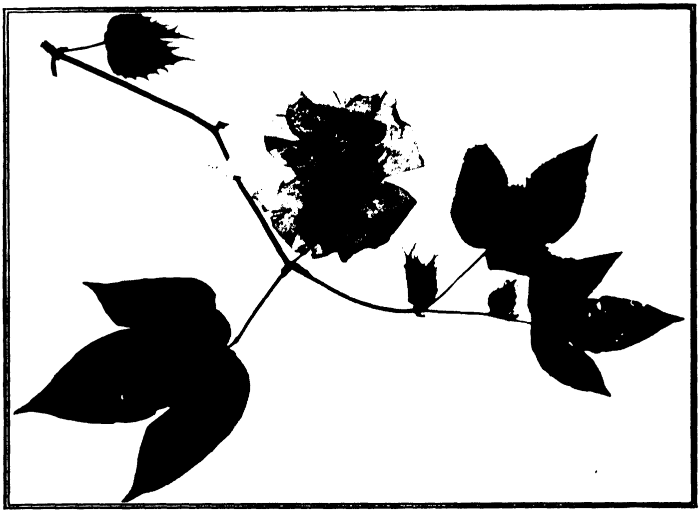

FIG. 2.—SEA ISLAND COTTON (GOSSYPIUM BARBADENSE).

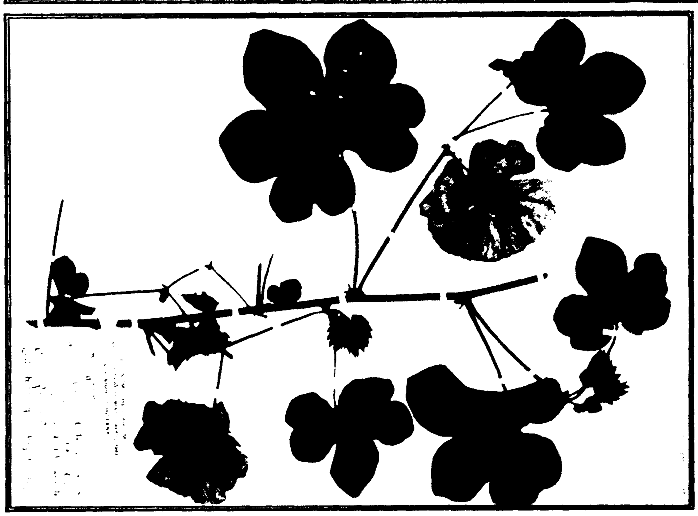

FIG. 3.—INDIA COTTON (GOSSYPIUM HERBACEUM).

cheaper cotton during the last century, it was used more extensively than any other vegetable fiber. In central and northern Russia, and in Holland, Belgium, Ireland, and northern Italy flax is still cultivated primarily for the production of fiber. In southern Russia, British India, Argentina, and the United States it is cultivated almost exclusively for seed production. In these regions the straw is burned, used for stable bedding, or sometimes for forage where there is a scarcity of hay. A small portion of the flax straw produced in North Dakota is used for paper stock, and in a few localities in the Dakotas, Minnesota, and Ohio it is made into upholstering tow. Only in the vicinity of Yale in eastern Michigan, at Northfield and Heron Lake, Minn., and at Salem and Scio, Oreg., is flax cultivated in this country for the production of spinning fiber. In all these localities the seed is saved, and it is doubtful if the industry would yield sufficient profits from the production of fiber alone to warrant its continuance under present conditions. All of the fiber flax of this country, as well as that of Ireland, Belgium, and Holland, is grown from seed of Russian origin. The plants deteriorate when grown from seeds of the third or fourth generation in this country, and unless special attention is given to selection and the production of improved strains it is necessary to import a new stock every three or four years.

Flax is a rather dainty surface feeder, with a small root system, yet it must make a rapid growth, reaching maturity in about one hundred days. It requires a soil with a sufficient amount of fertilizing elements readily available. It is apparently of still greater importance that the soil be continually moist during the growing season, and for the production of the best quality of fiber a moist atmosphere is essential. Carefully conducted experiments, as well as the observations of practical flax growers, have proved conclusively that this crop does not draw on the fertility of the soil as much as wheat, oats, or barley. It can not be cultivated year after year on the same land, because of a disease,[a] flax-wilt, the spores of which remain in the soil, infecting future crops. Since this disease does not attack other ordinary crops, flax may be introduced in a rotation, preferably after grass or pasture, once in six or eight years.

Flax is sown early in the spring, broadcast, like oats or wheat, either by hand seeder or with a drill. The seed should be covered evenly, and to a depth not exceeding an inch—one-half inch is better. No further attention is required until the crop is harvested late in July or early in August. The best flax is pulled, for the following reasons: (1) To secure straw of full length; (2) to avoid stain and injury which would result from soil moisture soaking into the cut stems while curing in the shock; (3) to secure better curing of the straw and ripening of the seed;

[a] Bolley. Bulletin No. 50, North Dakota Experiment Station.

and, (4) to avoid the blunt cut ends of the fiber. Flax that has not grown well enough to produce first-grade fiber is sometimes cut with a self-rake reaper. After curing in the shock for two or three weeks the seed is thrashed out, usually by holding an unbound bundle in the hands and passing the heads two or three times between rapidly revolving rollers which crush the seed pods, the seed afterwards being cleaned in a fanning mill. The straw is then bound into bundles and stored until time for retting, in October or early November. Nearly all of the fiber flax grown in the United States and Canada is retted by spreading the straw carefully and evenly on the ground, where it is exposed to the weather for two to four weeks. After retting, it is raked up, tied in bundles, and taken to the mills, where it is broken, scutched, and hackled. In each of these operations it is picked up and handled in small handfuls, and some of the processes, especially hackling, require a high degree of skill. Numerous machines have been invented to pull flax, spread it for retting, break it, and scutch the fiber, but none of them has given sufficient satisfaction to be generally adopted. Until machines are devised to take the place of hand labor and reduce the cost of the preparation of flax fiber there is little probability that the industry in this country can be increased in competition with other crops which may be cultivated with greater profit.

The importations of flax fiber amount to about $2,000,000 annually. Most of this comes from Russia, Belgium, and Holland. In Belgium and Holland the flax is retted by soaking in water, which produces a whiter, softer fiber, but the process is more laborious and expensive than the dew retting practiced in this country.

Flax fiber is from 12 to 36 inches in length, silvery gray when dew retted, yellowish white when water retted, capable of fine subdivision, soft and flexible, and is the strongest of the fine commercial bast fibers. It is used for making linen sewing thread, shoe thread, bookbinders' thread, fishing lines, seine twine, the better grades of wrapping twine and knit underwear, and for weaving into handkerchiefs, toweling, table linen, collars and cuffs, shirt bosoms, and dress goods. The finer grades of linen damasks are imported, as the weaving of these goods is slow work, and requires a kind of labor not commonly found in this country.

HEMP.

Hemp (Pl. XLVII, fig. 2) originated in western Asia. Like flax, it was cultivated for fiber several centuries before the Christian era, and, next to flax, it was the most extensively used vegetable fiber until the introduction of cheaper cotton and jute. Hemp is now cultivated commercially in Russia, Austria-Hungary, Italy, Turkey, China, Japan, and the United States. In Europe several rather distinct varieties of hemp are grown, the principal types being the Piedmont of France

and northern Italy; the Neapolitan of southern Italy; the Smyrna of Turkey and Asia Minor; and the Russian of Russia and Hungary. All of these, and also the Japanese, Chinese, and Kentucky (or China-American) hemp, belong to the same species, *Cannabis sativa* L. This is the only true hemp, but the name hemp is unfortunately applied to many other fibers, most of which are quite different in character. About 15,000 acres in this country are annually devoted to hemp production. Nearly all of this is in the bluegrass region of Kentucky. Small areas—less than 1,000 acres in all—are cultivated near Lincoln, Nebr., and at Gridley and Rio Vista, Cal. The total production of hemp fiber, varying from 6,000 to 9,000 tons, is not sufficient to supply the demands of our manufacturers, and more than 4,000 tons are imported annually, chiefly from Italy and Russia. Hemp fiber, prepared by water retting as practiced in Italy, is of a creamy-white color, lustrous, soft, and pliable. It makes a satisfactory substitute for flax, and is used for medium grades of nearly all classes of goods commonly made from flax, except the finer linens. When prepared by dew retting as practiced in this country, the fiber is gray, and somewhat harsh to the touch. It is used for yacht cordage, ropes, fishing lines, linen crash, homespuns, hemp carpets, and as warp in making all kinds of carpets and rugs.

JUTE.

Jute fiber is obtained from two closely related species, *Corchorus olitorius* and *Corchorus capsularis*, native in Asia. Both are cultivated largely in Bengal, India, and to a less extent in China, Japan, and Formosa. The plants are annuals, belonging to the linden family. In general habit of growth they resemble Kentucky hemp, attaining a height of 8 to 12 feet, with no branches or only a few small ones near the top. Jute grows best in rich alluvial soils along rivers. The seed is sown in the spring, either broadcast in the field or sometimes in carefully prepared beds, from which the seedlings are afterwards transplanted. The plants are harvested either by cutting close to the ground or by pulling them up by the roots. In Formosa the fiber is stripped from the fresh green stalks as soon as pulled, and these ribbons, called "hemp skins," are afterwards retted by soaking them in water, and the fiber cleaned by drawing it between a blunt knife and a block of wood. In India the jute is either cut or pulled, and is retted by immersing the bundles of stalks in water. The fiber is afterwards cleaned by hand processes from the wet stalks.

The coarser fiber from the base of the stalks, 5 to 25 inches in length, is cut off and placed upon the market as jute butts. The remainder of the fiber is fine, soft, glossy, pliable, and easily spun. When fresh it is of a light creamy-white color, but it changes to a dingy yellow upon exposure. It also loses its strength, especially if exposed

to moisture. It is the cheapest fiber used in American textile manufactures, and it is employed in greater quantities than any other except cotton and sisal. Jute butts, ranging in price from 1 to 2 cents per pound, are used for making paper, and also for coarse bagging, cotton-bale covering, and the cheaper grades of twine. The longer fiber, selling in this country for 2¾ to 3¼ cents per pound, is used for wool twine, binder twine, jute rugs and carpets, grain sacks, and even for filling in heavy silk goods. The importations of jute fiber and jute butts amount to more than 100,000 tons a year, and the consumption in this country is steadily increasing. Experiments in the cultivation of jute in this country have proved that the plants may be grown successfully in the Southern States, but without suitable machinery for preparing the fiber the industry can not be carried on profitably.

HARD FIBERS.

MANILA FIBER.

Manila fiber, often called manila hemp, is obtained from the leaf sheaths of a kind of banana plant native in the Philippines. There are several varieties recognized in the different provinces, but all are known by the name abacá, and all have been regarded heretofore as belonging to one species, *Musa textilis* (Pl. XLVIII, fig. 1). Recent investigations conducted by the Bureau of Agriculture of the Philippines indicate that there are probably several distinct but closely related species cultivated for the production of manila fiber.

Abacá plants are cultivated successfully only in a comparatively small portion of the Philippines—in southern Luzon, and in Mindanao, Negros, Leyte, Cebu, Masbate, Mindoro, Marinduque, and Samar. In these regions there is an abundant rainfall and a relatively high humidity of the atmosphere. The plant grows best in volcanic soil on hillsides where there is good natural drainage. It can not be grown successfully in wet, swampy land or in soil that becomes dry.

The plants are propagated chiefly by suckers, which spring from the roots of mature plants. These are set out in rows 5 to 8 feet apart in each direction. Cultivation consists chiefly in cutting down weeds which would otherwise grow up and choke out the abacá. About three years are required for the plants to reach maturity when propagated from cuttings, or about five years when grown from seeds. They attain a height of 8 to 20 feet, the trunk being composed chiefly of overlapping leaf sheaths. When the flower bud appears the entire plant is cut off close to the ground. The leaf sheaths, 5 to 12 feet in length, are stripped off, separated tangentially into layers a quarter of an inch or less in thickness, and these in turn split into strips 1 to 2 inches in width. While yet fresh and green these strips are drawn by hand under a knife held by a spring against a piece of wood. This scrapes away the pulp, leaving the fiber clean and white. After

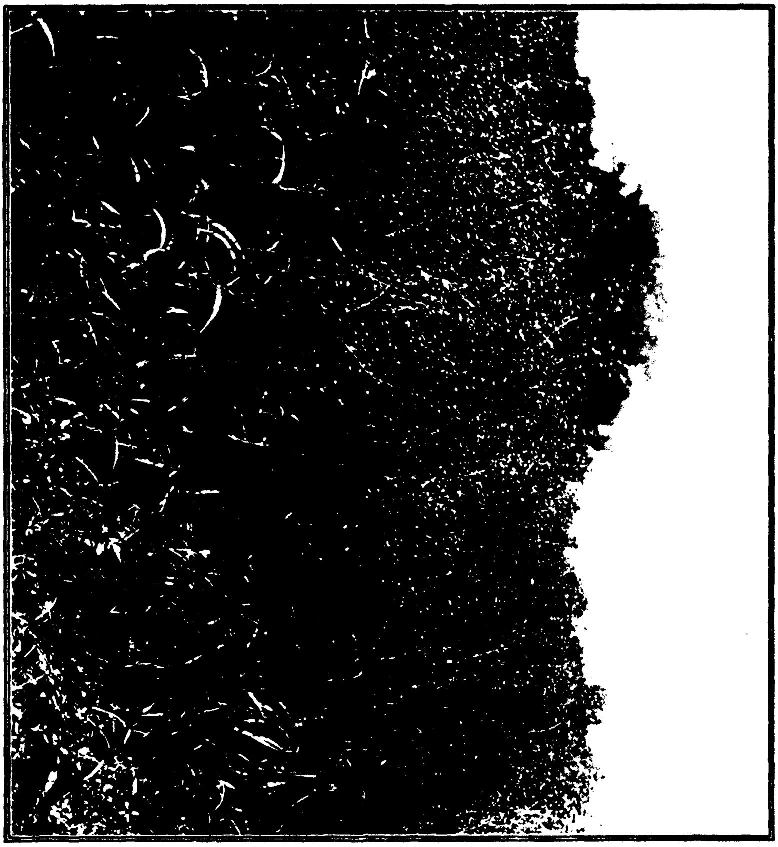

FIG. 1.—FLAX GROWN FOR FIBER AT NORTHFIELD, MINN., READY FOR HARVEST.

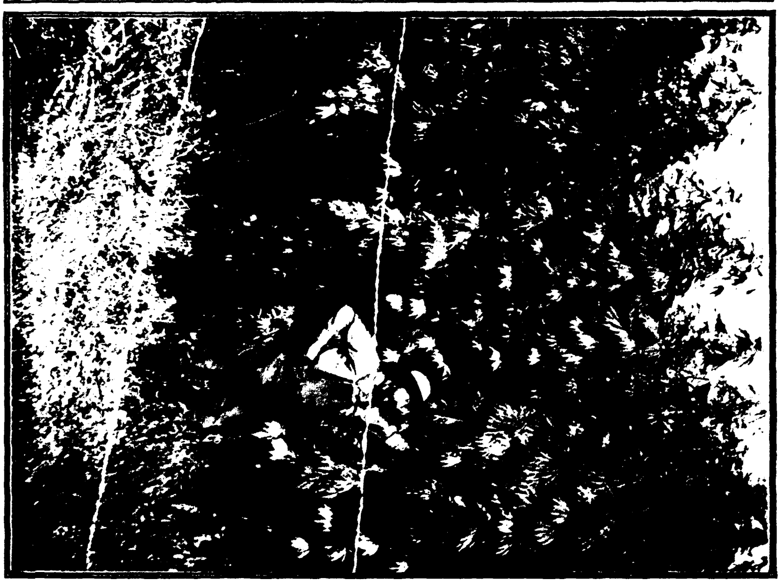

FIG. 2.—HEMP ON ALLUVIAL SOIL AT GRIDLEY, CAL.

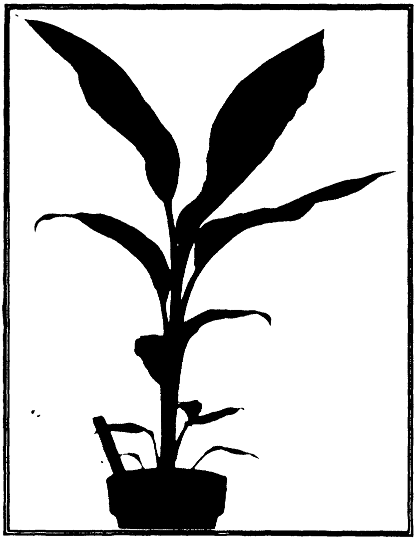

FIG. 1. ABACA, SEEDLING OF PLANT PRODUCING MANILA FIBER.

FIG. 2.—NEW ZEALAND "FLAX."

FIG. 3.—SISAL PLANTS. GROWING IN THE BAHAMAS.

drying in the sun the fiber is tied in bunches and taken to the principal towns or to Manila to be baled for export.

The average yield of fiber is about 650 pounds per acre. The price in the New York market during the past ten years has ranged from 4 to 14 cents per pound. Manila fiber ranks first among the resources of the Philippine Islands, amounting to more than 60 per cent of the total value of exports. The importation of this fiber into the United States has been rapidly increasing since the war of 1898. During the calendar year 1903 more than 500,000 bales of 270 pounds each were brought to this country.

The best grade of manila fiber is of a light buff color, lustrous, and very strong, in fine, even strands 6 to 12 feet in length. Poorer grades are coarser and duller in color, some of them yellow or even dark brown, and lacking in strength. The better grades are regarded as the only satisfactory material known in commerce for making hawsers, ships' cables, and other marine cordage which may be exposed to salt water, or for well-drilling cables, hoisting ropes, and transmission ropes to be used where great strength and flexibility are required. The best grade of binder twine is made from manila fiber, since owing to its greater strength it can be made up at 650 feet to the pound as compared with sisal at 500 feet.

SISAL.

The sisal plant (*Agave rigida*) usually known as henequen in Spanish-speaking countries, is native in Yucatan (Pl. XLVIII, fig. 3). It has been introduced in many other tropical countries, but its cultivation for fiber on a commercial scale is confined to Yucatan, the Bahamas, Turks Island, Cuba, and Hawaii. Recent plantations have been made in Venezuela, in Santo Domingo, and in the Bombay and Madras presidencies in India.

The sisal plant requires for its best development a soil composed chiefly of limestone and a warm and comparatively dry climate. Clear, dry weather, with bright sunshine, is required to dry and bleach the fiber, while in rich, moist soil or in a moist climate the leaves develop too large an amount of pulp in proportion to the fiber.

The sisal plant is propagated by suckers springing from the roots of old plants, or from bulbils. Bulbils, called "mast plants," are produced in great numbers on the flower stalks in place of seed pods, like onion sets. The plants are set out during the rainy season, in rows 4 to 8 feet apart, in holes dug in partly disintegrated coral or lime rock with crowbars, pickaxes, and sometimes with the aid of dynamite. The ground where sisal is grown is usually too rocky to permit any stirring of the soil. About the only care given is to cut the brush and weeds once or twice each year. The weeds and brush, largely leguminous plants, by decaying on the ground add fertility to the soil. The first crop of outer leaves of the plants is cut at the end of three years when grown

from suckers, or four years when grown from mast plants. From ten to twenty leaves are produced each year for a period of twelve to twenty-five years in Yucatan, ten to fifteen years in Cuba, and six to twelve years in the Bahamas. An unusually cold winter at any period tends to check growth and cause the plants to send up flower stalks, after which they die.

Sisal fiber is cleaned from the leaves by machines which scrape out the pulp and at the same time wash the fiber in running water. It is then hung in the sun to dry and bleach for from one to three days, after which it is baled for market. The average annual yield is about 600 pounds of clean, dry fiber per acre. The price during the past ten years has varied from 2¾ to 10 cents per pound. More than 600,000 bales, averaging about 360 pounds each, were imported during the calendar year 1903.

Sisal fiber of good quality is of a slightly yellowish-white color, 2½ to 4 feet in length, somewhat harsher and less flexible than manila fiber, but next to that the strongest and most extensively used hard fiber. It is used in the manufacture of binder twine, lariats, and general cordage, aside from marine cordage and derrick ropes. It can not withstand the destructive action of salt water, and its lack of flexibility prevents it from being used to advantage for running over pulleys or in power transmission. It is used extensively in mixtures with manila fiber.

NEW ZEALAND HEMP.

The plant producing the fiber known in our markets as New Zealand hemp or New Zealand flax is a perennial belonging to the lily family, and is technically known as *Phormium tenax* (Pl. XLVIII, fig. 2). It is native in the coast regions of New Zealand, and is cultivated commercially only in those islands. The plant is hardy, withstanding a considerable degree of cold and drought. It is cultivated as an ornamental plant in parks and private grounds in the coast region of California, and also on the west coasts of Ireland and Scotland. Several different varieties are cultivated in New Zealand, some with leaves 6 to 8 feet long, others with leaves only half that length, 1½ to 3 inches in width, and of rather thin texture. The fiber is cleaned from the freshly cut leaves by scraping, washing, and drying. The scraping process is performed chiefly by machinery, but no machine has yet been used which will do all of the work satisfactorily.

The fiber is 40 to 60 inches long, nearly white, fine, and rather soft for a leaf fiber. It is used as a substitute for sisal in binder twine, baling rope, and medium grades of cordage, and is made up largely in mixtures with manila or sisal, except in the cheaper tying twines. By extra care in preparation and hackling, a quality is produced almost as fine and soft as the better grades of flax, and when thus prepared it may be spun and woven into goods closely resembling linen. Before

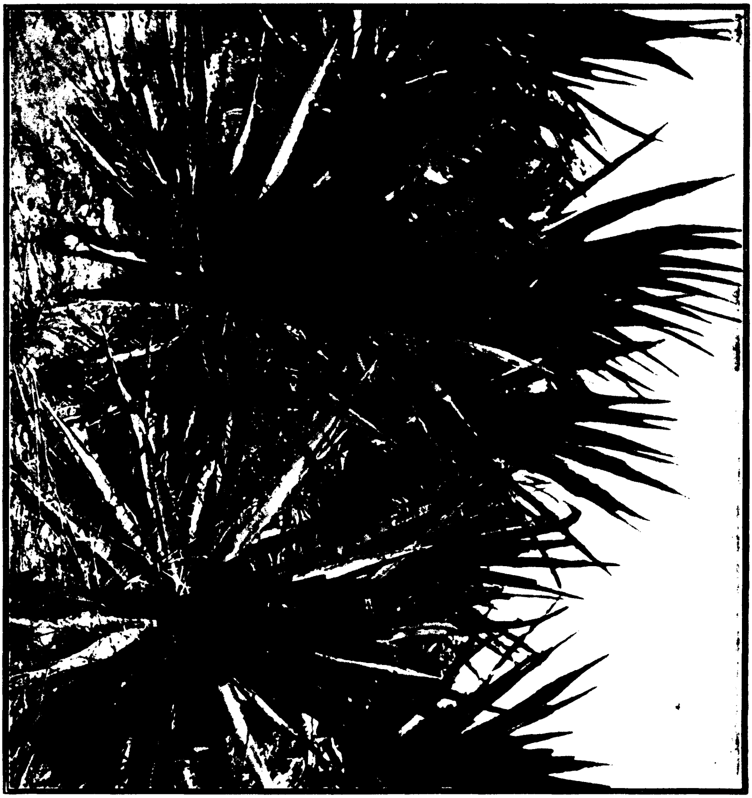

Fig. 1. Lechuguilla Plants, Producing Jaumave Istle.

Fig. 2.—Palma Samandoca, from which Palma Istle is Obtained.

being exported from New Zealand the fiber must all pass a rigid inspection, to insure uniformity in grading and prevent the shipment of inferior qualities. Since this system of inspection went into effect, in 1901, the importations of New Zealand hemp into this country have increased from 3,915 to 10,674 tons annually, and the price has advanced from $110 to $142 per ton.

MAURITIUS.

Mauritius fiber or mauritius hemp, as it is often called in the market, is obtained from the large, fleshy leaves of an agave-like plant (*Furcræa fœtida*). This plant is widely distributed in the tropics of both hemispheres. In Porto Rico it is known as maguey, probably from its resemblance to the maguey of Mexico, and in Hawaii it is called malino, a corruption of manila.

The fiber is produced commercially only on the island of Mauritius, though there seems to be no good reason why the industry should not succeed elsewhere. The plant is more hardy and thrives under a greater diversity of soil and climatic conditions than any other important fiber plant of this class. It is propagated by suckers or by bulbils in the same manner as sisal, and the fiber is cleaned partly by machinery. The preparation of the fiber involves the same processes, scraping, washing, and drying, as in the case of sisal. Under favorable conditions the yield ranges from 1,000 to 1,500 pounds per acre. The fiber is whiter and softer than other hard fibers, but it is weaker than sisal. It is used in the manufacture of gunny bags, halters, and hammocks, but more largely for mixing with manila and sisal in making medium grades of cordage. When the better grades of cordage fiber (manila and sisal) are abundant and quoted low in the market, mauritius is likely to fall below the cost of production.

ISTLE.

The increasing demand for cordage and twines of all kinds during the past few years has led to the substitution of istle fiber for the cheaper grades, whereas this fiber had been regarded heretofore as suitable only for use in the manufacture of brushes.

Istle or Tampico fiber is produced by four or five different species of plants which grow on the high arid table-lands of northern Mexico. The most important of these are the Jaumave lechuguilla (pronounced How-mah′-ve lech-u-guee′l-ya), producing the best grade, Jaumave istle (Pl. XLIX, fig. 1); lechuguilla, producing a medium grade, Tula istle; and palma samandoca and palma pita, producing palma istle, about equal in value to Tula istle.

The production of Jaumave istle is confined chiefly to the fertile Jaumave Valley, about 70 miles by road over the mountains south of Victoria, in the State of Tamaulipas. The fiber is obtained from the leaves of an agave plant, known technically as *Agave lophantha*. The

plant is not cultivated, but it grows abundantly on the mountain sides and out on the gravelly plain at the base of the mountains. Only the young inner leaves, forming the central spindle-like bud, are used. These are collected and the leaves taken up one by one and cleaned by drawing them, first one end then the other, under a blunt knife pressed against a block of wood. More than 30 tons of this fiber are produced in the vicinity of Jaumave every week, and all of it is shipped on the backs of burros over the mountains, a long two days' journey, to the railway at Victoria.

Tula istle is obtained from the lechuguilla plant (*Agave lecheguilla*), which is widely distributed on the high lands of Mexico and extends into western Texas and New Mexico. The fiber is produced most abundantly in the vicinity of Tula, about 60 miles south of Jaumave, in the State of Tamaulipas. It is obtained from the inner leaves of the plant, and is cleaned in exactly the same manner as Jaumave istle.

Palma istle is obtained from the inner leaves of yuccas, known in Mexico as palmas. The species producing most of this fiber is called palma samandoca (*Samuella carnerosana*—Pl. XLIX, fig. 2). This plant has a trunk 6 to 15 inches in diameter, and attains a height of 6 to 15 feet, bearing at the top a dense cluster of sword-like leaves, 20 to 30 inches long. Some of the palma istle is produced by the plant known as palma loco, or palma pita (*Yucca treculeana*), found in Coahuila and Nueva Leon. This yucca is very similar in appearance to palma samandoca, though usually with shorter trunk and longer leaves. The central cluster of unopened young leaves is collected and cleaned in the same manner as the leaves of the lechuguilla plants, except that they have to be steamed two to four hours to loosen the tissues before the pulp can be scraped out. The fiber is discolored by the steaming process, but this is partly corrected by bleaching in the sun as it dries.

Palma istle fiber is 15 to 35 inches in length, usually coarser and stiffer than sisal, yellow in color, and somewhat gummy. Tula istle is 12 to 30 inches long and nearly white in color. Jaumave istle is 20 to 40 inches long, rarely longer, almost white, and nearly as strong and flexible as sisal. The importations of istle fiber into the United States have increased from less than 4,000 tons in 1900 to more than 12,000 tons in 1903. Istle fiber has long been used as a substitute for bristles in the manufacture of brushes, and it is now being employed in increasing quantities in the cheaper grades of twine, such as lath twine, baling rope, and medium grades of cordage. Introduced at first as an adulterant or substitute for better fibers, it seems destined to find, through improved processes of manufacture, a legitimate place in the cordage industry. If machines are devised for cleaning this fiber in a satisfactory manner it is thought that the thousands of acres of lechuguilla plants in western Texas may be profitably utilized.